Chapter 5
Gates, Valves, Bulkheads and Guides, Trashracks, and Operating Equipment

5-1. Functions and Requirements

Gates, valves, and bulkheads in intake structures serve a number of different functions related to the purposes of the project. Type, location, arrangement, layout, and design will depend on the various operational, maintenance and servicing, dam safety, and construction (if used for diversion) requirements. Further discussion and details on gates and valves are provided in *Advanced Dam Engineering for Design Construction and Rehabilitation* by Robert Jansen and EM 1110-2-1602, Chapter 3.

a. *Low-level drawdown intakes.* Low-level drawdown intakes are required on new projects to lower the reservoir below minimum pool elevation or to provide a dry reservoir behind the dam. The reasons for this capability may include provisions to draw down the reservoir for inspection after a seismic event, for periodic inspections and repair of features or structures normally submerged, to flush fine sediment accumulations in the reservoir, to provide flexibility for changes in reservoir regulation, and to provide no pool during low flows to meet environmental requirements. Whether these intakes are gated or bulkheaded will depend on economics, frequency of use, and the type of operation. The criteria for low-level drawdown are addressed in ER 1110-2-50.

b. *Control gates.* The control gates located in each gated passage to the outlet tunnel or conduit generally consist of an emergency gate followed by a service gate. Guides are provided just upstream of the gates for stoplogs or a bulkhead. The number of gates and passageways, size, types, and layout in relation to the structure will depend on the project purpose(s); the hydraulic design, operation, and flow regulation requirements; hydraulic head; and structural design, construction, and economic requirements. Hydraulic criteria for the design of gates are discussed in EM 1110-2-1602.

(1) Service gates. Service gates are used for flow regulation, and one gate is required for each water passage. For low- and medium-head conditions, the type of gate may be a tractor (mechanically or hydraulically operated), hydraulically operated slide gate, or hydraulically operated tainter gate. For high-head conditions, hydraulically operated slide gates are generally preferred for long periods of operation at partial gate openings.

(2) Emergency gates. Emergency gates should be located within the intake structure immediately upstream of the service gates. Emergency gates are required in reservoirs having water conservation, power, or a similar type pool to prevent loss of stored water if a service gate is inoperable (see EM 1110-2-1602, Chapter 3, Section III, Gate Passage Requirements for additional guidance on emergency gate requirements). Emergency gates must be designed to close under free flow at the maximum conservation or power pool. However, emergency gates are not required to regulate flow, as a service gate, because sufficient conservation or power releases can be made through the remaining facilities. Typically, emergency gates are of the same type as the service gate; however, for low- and medium-head conditions, a single transferable tractor gate installed by a traveling hoist at the operating deck near the top of the structure may be used. Emergency gates must be designed to withstand the maximum reservoir head at stresses not exceeding 33-1/3 percent of the basic stress.

c. *Water temperature and quality.* Projects providing temperature or water quality controls may have multi-level intake ports or telescoping weirs with a mixing wet well. The intakes may be gated or ungated. Flow regulation with control gates is required downstream of the wet well.

5-2. Gate Types

A wide variety of gates have been used in outlet works. The principal types of regulating gates on U.S. Army Corps of Engineers dams for heads of 100 ft or more are hydraulic slide gates, caterpillar gates with cable hoists, hydraulic caterpillar or wheel gates, and hydraulic tainter gates. The type selected depends on the purpose, operating characteristics, flow regulation requirements, maintenance and serviceability, and life-cycle cost.

a. Hydraulically operated slide gates. The hydraulically operated slide gate has a record of dependability and low maintenance and is capable of providing fine regulation. These gates have been designed for projects up to approximately a 500-ft head. Compared to the tractor or roller gates and tainter gates, hydraulically operated slide gates for high heads are smaller because of the much greater operating force per square foot of gate and the greater rigidity required to meet the operating requirements. The gate is housed in steel gate frames with attached conduit liners requiring close fabrication tolerances to provide a watertight unit. The assembly is embedded and anchored directly in the main concrete body. The seating or sealing surfaces of embedded gate frames must be accessible for inspection and maintenance. Cavitation problems have occurred in the gates' leaf bottom edges and the gate frame downstream of the gate under high-velocity flow conditions at small gate openings.

b. Roller- and wheel-mounted gates. Roller-mounted (tractor or caterpillar) gates have roller trains mounted on the gate parallel to the gate slot, and wheel-mounted gates use fixed wheels attached to the gate. Both gate types can be hydraulically operated or are suspended with cable hoists and hydraulically operated gates for low-flow regulation. The cable hoist gates are not as positive for low-flow regulation as other gates because of the elastic properties of the cables. These types of gates are used for heads up to about 200 ft. A gate frame and conduit liner are provided with the gate. The roller trains and wheels on the gates are vulnerable to seizing caused by corrosion and debris.

c. Tainter (radial) gates. Radial gates are simple, reliable, and generally less expensive than other gates of equal size. They are satisfactory for low-flow regulation. Because gate slots are not required, head loss is minimized. Top seals may limit heads to about 250 ft. Eccentric trunnion designs have been used to facilitate sealing. In some cases, vibration has resulted where bottom leaf seals and beams were not properly designed.

5-3. Bulkheads and Guides

A bulkhead or stoplog and guides should be provided at the entrance to each water passage for dewatering the service and emergency gates for maintenance except when they are excessively costly or clearly unfeasible and other means can be improvised. When emergency gates are not required, stoplog or bulkhead guides for maintenance should always be provided upstream of the service gates.

5-4. Trashracks

Trashracks are needed to prevent clogging and debris damage to outlet control gates and turbines. The trash-rack type and size of openings depend on the pool elevation, intake elevation, the size of the outlet conduit, the reservoir trash conditions, type of control device used, use of the water, and the need to exclude the trash.

a. Intakes for flow regulation. A simple trash structure, usually of reinforced concrete, with clear horizontal and vertical openings not more than two-thirds the gate width should be provided at the upstream end of the outlet works to catch trees and other large trash which may reach the entrance and be capable of blocking the gated passages (EM 1110-2-1602, Chapter 3, Section II). Large trash at the tunnel entrance occurs more often when the permanent pool is only slightly above the entrance than when the permanent pool is high above the entrance. Only in special cases in which trees and floating debris are absent from the reservoir and watershed should the trash structure be omitted.

(1) Metal trashracks fabricated of closely spaced bars are generally used for small conduits with control valves and water supply intakes that require screening of small debris.

(2) To facilitate trash removal immediately after a flood, the working platform at the top for raking and removal of trash usually should not be lower than the top elevation of the conservation or maximum power pool. The usual trash structure consists of upright beams, inclined slightly downstream from the vertical to facilitate raking, and horizontal beams.

(3) If the gate structure is located at the upstream end of the outlet tunnel, the trash structure is combined with it for economy.

(4) The area of the openings in the trash structure should limit the local net-area velocity to less than 10 to 15 ft/sec.

b. Power intakes. EM 1110-2-3001 discusses the requirements for power intake trashracks and the design loads and spacing of trashracks from the standpoint of hydraulic and structural requirements.

c. Floating trash and debris control facilities. Floating trash and debris control can be provided by a basic trash boom constructed of logs or floating pontoons. Trashracks would still be necessary to protect intakes from occasional water-logged trees or large logs that pass under the trash boom.

5-5. Load Cases

a. Gates, valves, bulkhead, and stoplogs. The gates, valves, bulkhead, and stoplog design loads should include dead loads, static live loads, dynamic live loads, temperature loads, and any unusual load which can potentially occur due to misoperation. Dead loads include self weight and the weight of the attached equipment. The static live load includes interior and exterior water surface pressures, silt pressures, temperatures, debris, ice, lifting and installation forces on components, and any other loading pertinent to the project operation. Dynamic loads include seismic, dynamic hydraulic conditions, load rejection for power intakes, vibration, fluctuating hydraulic forces, waves, and hydraulic drawdown forces for closure under flow conditions.

b. Trashracks. The trashrack structure should be designed to withstand hydraulic pressure based on velocity head loss with a minimum design head of 5 ft. External forces resulting from reservoir ice, debris clogging, and sediment buildup should be considered in the design at projects where those conditions apply.

5-6. Strength and Serviceability Requirements

Strength and serviceability requirements have an important bearing on the development and design of gates, valves, bulkhead and guides, trashracks, and operating equipment. The types of factors that should be considered include frequency and intensity of operation, cavitation and abrasion during operation, maximum deflection for operation, vibration and hydrodynamic loading, corrosion, and maintainability. Gates, bulkheads, stoplogs, trashracks, and other steel features should be designed in accordance with the strength and serviceability requirements presented in EM 1110-2-2105.

5-7. Gate Room Layout/Operating Equipment

a. Gate room layout. The gate room layout will depend on the mechanical equipment and electrical controls which will be located in the room. Adequate room size must be allowed for safe clearance and maintainability of operating equipment such as gate operators, valves, and electrical components. The room must also have adequate clearance for removal of the gates and valves. Vertical intake structures generally utilize a crane on the intake deck to disassemble and remove items requiring major maintenance. This work requires that hatches be provided to facilitate removal of components. Inclined intake structures may require a bridge crane in the gate room for disassembly of components. Lifting eyes should be strategically placed in the gate room along with provisions for monorail hoists, if necessary.

b. Operating equipment. Additional information about gates and valves is provided in EM 1110-2-1602, Hydraulic Design of Reservoir Outlet Works; EM 1110-2-2702, Design of Spillway Tainter Gates, and UFGS 11287A, Tainter Gates and Anchorages.

(1) Slide gates. Slide gates are typically hydraulic cylinder operated. The hydraulic power units can be package units. Two pump/motor combinations are used, with the hydraulic piping valved in such a way that one pump may be removed from service without rendering the system inoperative. A mechanical position indicator can be used to show the gate opening. This position indication is converted into an electronic signal for remote sensing and operation. Figure 5-1 shows a typical gate room layout with slide gates.

(2) Roller gates. Roller gates can be operated by the use of hydraulic cylinders or wire rope hoists. Position indication can be noted by use of an indicator rod or, in the case of hoists, by use of a revolution counter.

(3) Tainter gates. Tainter gates are typically hoist operated. A single motor/reducer drives a torque tube which drives a wire rope drum on each end of the tainter gate.

(4) Valves. Valves are generally electric motors operated from a pushbutton station, both locally at the valve and at a control in the gate room. Types of valves include ball valves, which act as a guard valve to fixed-cone valves in a minimum discharge type outlet, and gate valves, which are used in a main outlet conduit fill pipe.

(5) Controls and instrumentation. Controls and instrumentation for gate or valve positioning, emergency generator, and sump and utility pumps may be local, remote, or both. Piezometers, flow meters, and level gauges are discussed in EM 1110-2-4205, Hydroelectric Power Plants Mechanical Design.

c. Other equipment. Heating and ventilating of the gate room are generally achieved through the use of a ventilation fan, duct work, and unit heaters located strategically in the gate room. Minimum outdoor air quantities should be required in accordance with American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) criteria. Special design features may be required in situations where the possibility of infiltration of gases from the decay of vegetation into the tower exists. Emergency power is usually provided by an emergency generator located at the top of the intake tower. However, in towers, emergency power may be provided by an emergency generator located in a remote building away from the intake tower. Sump pumps are normally required at the lowest point of the tower. When sump pumps are required, the discharge is pumped into the reservoir through an oil/water separator. Overhead cranes (bridge type or monorail) may be included to facilitate maintenance functions. The coverage envelope should be large enough to permit access to all gates and valves.

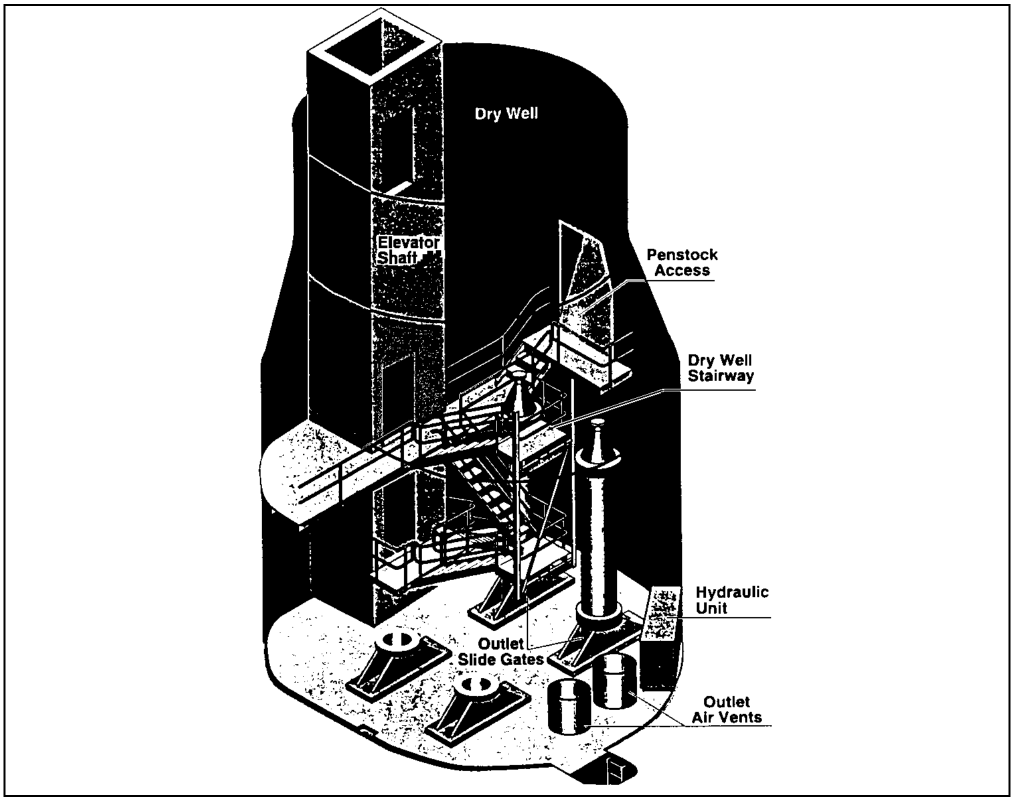

Figure 5-1. Gate room perspective

5-8. Elevator

Design and justification factors for elevators are discussed in EM 1110-2-4205, Hydroelectric Power Plants Mechanical Design. UFGS 14210A, Elevators, Electric, should be in accordance with American Society of Mechanical Engineers (ASME) A17.1, Safety Code for Elevators and Escalators.